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# BALLANTINE LABORATORIES, Inc.

INSTRUCTIONS FOR

# SENSITIVE ELECTRONIC VOLTMETER

MODEL 302-B

BOONTON, NEW JERSEY

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# SPECIFICATIONS

## BALLANTINE MODEL 302B ELECTRONIC VOLTMETER

### Frequency Range
2 - 150,000 c.p.s.

### Voltage Range
100 microvolts to 100 volts in 6 decade ranges.
(.001, .01, .1, 1, 10, 100 volts full scale)

### Accuracy
3% except 5% below 5 c.p.s. and above 100,000 c.p.s.

### Input Impedance

| Range Switch Setting | Input Impedance |
|---|---|
| 0.001 and 0.01 Ranges | 2 megohms shunted by 15 mmfds |
| 0.1 Range | 2.2 megohms shunted by 8 mmfds |
| 1, 10 and 100 Ranges | 2.0 megohms shunted by 8 mmfds |

### Scales
Logarithmic voltage scale reading from 1 to 10; Auxiliary scale in decibels from 0 to 20. Each meter is hand calibrated.

### Tubes
Six Type 1U4. All Tubes supplied.

### Amplifier Characteristics
Maximum voltage gain of 60 DB, adjustable by means of range switch to 40 or 20 DB. Output impedance about 3000 ohms. Maximum output voltage 1 volt. Flat within 1/2 DB.

### Batteries
Four Eveready Type 467: Four Burgess Type 2F. Battery life 100 hours or more in normal use.

### Dimensions
6-7/8" wide, 7½" high, 12-3/8" long

### Weight
15 pounds

9/17/52

# INSTRUCTIONS FOR

# BATTERY-OPERATED ELECTRONIC AC VOLTMETER

# MODEL 302B

1. GENERAL - This instrument is designed to measure sinusoidal voltages from 100 microvolts to 100 volts over a frequency range from 2 to 150,000 c.p.s. By means of a six decade range switch, this entire voltage range is indicated on a single logarithmic voltage scale reading from 1 to 10. The indicating meter also has a linear decibel scale numbered from 0 to 20 decibels. The zero of the decibel scale is arbitrarily arranged for maximum usefulness so as to correspond to 1 on the voltage scale.

The fact that this voltmeter is powered by its own batteries makes it particularly useful in cases either where no external AC power source is available or where it is not desirable to use 110 volts AC because of limitations imposed by grounds or by even a small amount of residual 60 cycle hum.

Its accuracy is 3% between 5 and 100,000 c.p.s. and 5% below 5 and above 100,000 c.p.s.

An AC output jack permits the amplifier section of the voltmeter to be used as a flat high gain amplifier with an exact gain of 20, 40 or 60 DB depending on the setting of the range switch.

2. GENERAL CIRCUIT DESCRIPTION - This instrument consists of two 3-stage feedback amplifiers, a full wave crystal diode rectifier and a logarithmic indicating meter responding to the average values of the voltage wave but calibrated in rms values of a sine wave. The second of the two amplifiers incorporates the crystal rectifier in its feedback

loop thereby improving the linearity of the rectifier action. Each of the amplifiers has sufficient feedback to render the indications of the instrument substantially independent of changes in battery voltages, tubes and other circuit components. Part of the range switch attenuator is placed between the two amplifiers thereby reducing tube noise and microphonics to a minimum. For further circuit details see the attached diagram.

3. TUBES AND BATTERIES - The tube complement consists of six Type 1U4 tubes all of which are supplied. The voltmeter is powered by 4 Burgess Type 2F "A" batteries and by two sets of 2 Eveready Type 467 "B" Batteries (1 set for each amplifier).

The batteries are indicated on the attached circuit drawing as $A_1$, $A_2$, $A_3$, $B_1$ and $B_2$ respectively. (Note that battery $A_1$ is composed of two type 2F batteries in parallel). If the voltmeter is to read within the limits of its specified accuracy the voltages of the various batteries when the voltmeter is switched on must be not less than the following values: $A_1$ - 1.2 volts; $A_2$ and $A_3$ - 1.0 volt each: $B_1$ - 115 Volts; and $B_2$-112 Volts (Note: in checking the "B" voltages a meter of not less than 1000 ohms per volt should be employed). To obtain access to the batteries, follow the procedure described below. If all batteries are fresh when installed, the "B" battery $B_1$ will be the first to reach the minimum permissible voltage. In order therefore to simplify the testing of the condition of the batteries, provision is made for testing the voltage of battery $B_1$ on the indicating meter of the voltmeter. When the "OFF-BATT. TEST-ON" Switch is turned to the "BATT.TEST" position a reading of 8 or more on the upper scale of the indicating meter indicates that the voltage of battery $B_1$ is 115 volts

or higher. Because of the indicating meter damping a few seconds should be allowed for attaining maximum indication. If the indicating meter shows a reading of less than 8, all the batteries should be replaced since the batteries other than $B_1$ will only operate for a relatively short time before they, too, will fall below their minimum permissible voltages.

The battery life should at least be 100 hours with normal usage of 4 hours per day. The batteries are accessible when the panel is removed from the outer case by loosening the four nickel plated screws (not the Phillips head screws) on the face of the panel. The battery replacements should be installed as shown on the attached drawing. The plugs terminating the battery cable assure proper polarity connection to the batteries. Care should be taken that the "B" battery connector marked $B_1$ and $B_2$ are connected to the $B_1$ set and the $B_2$ set of B batteries respectively.

It is recommended that batteries be removed from the case as soon as they become exhausted, otherwise they may swell and be difficult to remove.

4. OPERATION - The input terminal of the voltmeter marked GND is connected to the panel and to the box which houses the instrument. If it is desired to connect the voltmeter's "grounded" terminal to a point in the circuit at a high potential above ground, the user should exercise the customary safety precautions before touching the voltmeter since its case will be at the same high potential above ground.

First turn the decade range switch to the proper decade for the voltage to be measured. The position of the range switch indicates

the voltage input to yield full scale deflection of the indicating meter. Next check the condition of the "B" batteries by turning the "OFF-BATT, TEST-ON" switch to the "BATT. TEST" position. A reading of "3" or above indicates satisfactory "B" voltage. If the reading is less than "3" all the batteries should be replaced as outlined in Paragraph 3. Next turn the "OFF-BATT, TEST-ON" switch fully clockwise to the "ON" position. Because of the large capacitors employed to achieve the low frequency response of this voltmeter, about 20 seconds is required after first turning on the voltmeter to enable it to reach a condition of equilibrium. This condition will be indicated by the meter needle assuming a stationary position after drifting over the scale for a short time.

The "High Damping" position of the meter damping switch connects an additional capacitor across the indicating meter. This increases the damping of the indicating meter and enables needle flutter to be substantially reduced or entirely eliminated when reading frequencies of a few cycles per second or when the voltage under measurement has random fluctuation due to noise, etc. The voltmeter should not be used with the damping switch in the "High Damping" position except when necessary to eliminate needle flutter because, while the added damping does not affect the accuracy of the readings, the meter requires more time to respond to change in voltage with the added damping than without it.

5. INPUT IMPEDANCE - Any direct current component of the wave under measurement is kept out of the instrument by means of a series blocking condenser. The input impedance of the voltmeter depends somewhat on the setting of the range switch as shown by the following table.

| RANGE SWITCH SETTING | INPUT IMPEDANCE |
|---|---|
| 0.001 and 0.01 Ranges | 2 megohms shunted by 15 mmfds. |
| 0.1 Range | 2.2 megohms shunted by 8 mmfds. |
| 1, 10 and 100 Ranges | 2 megohms shunted by 8 mmfds. |

6. OVERLOAD CHARACTERISTICS - The amplifier circuits are designed to saturate promptly when the voltage exceeds the full scale indication of the meter, thus protecting the meter movement. This is a considerable advantage over other meters which may be seriously damaged by overloads such as the Model 302B will withstand. Overloads amounting to several hundred to one can be safely withstood on the lower ranges, while on the 10 and 100 volt ranges the maximum safe voltage is 400 volts.

7. EFFECT OF WAVE FORM - The indications of this voltmeter are proportional to the average value of the a-c wave under measurement. Since, however, it is primarily intended to measure sinusoidal waves its calibration is in terms of the rms value of a sinusoidal wave. Since electronic voltmeters of the diode rectifier type respond to the peak values of a wave, the readings of such meters and the present voltmeter will not necessarily agree when harmonics are present. The amount of the discrepancy will depend on the number and magnitude of the harmonics present as well as their phase relationship with respect to the fundamental. In all cases however, the departure of the readings from true rms values due to the presence of harmonics will be considerably less with an average responding meter such as the 302B than with a peak responding meter.

Furthermore since the 302B voltmeter responds to the average value of the a-c wave, "turn-over" discrepancies occasioned by any lack of

symmetry of the wave such as are experienced in half-wave peak reading instruments are eliminated.

8. RANGE ADJUSTMENT - Range adjustment is made by means of the red adjusting screw on the case of the indicating meter. Its function is to bring the 10 on one range to exactly 1 on the next higher range. Ordinarily no adjustment should be necessary other than for high ambient temperatures above 30°C where the efficiency of the meter rectifiers diminishes slightly. If some discrepancy is noted the adjustment should be made as follows: Connect a stable source of about 10 volts pure sinusoidal a-c at any convenient frequency from 50 to 10,000 c.p.s. to the input. Adjust this source so that the meter reads full scale (10) on the 10 volt range. Switch to the 100 volt range. The meter should now read 1. If not, the red adjusting screw should be rotated until it does so. Switch back to the lower range to check that the meter still reads 10. If not, readjust the input voltage to 10 and switch back to 1, readjusting with screw driver if necessary. When it is not convenient to obtain a source of 10 volts the 1 and the 10 volt ranges may be similarly used to make this adjustment by using a source of 1 volt. (Since the input impedance of the voltmeter on the 0.1 volt range is slightly higher than on the other ranges the use of this range is not recommended in making this range adjustment unless the impedance of the voltage source is less than 50,000 ohms).

In the past some users have misunderstood the purpose of the meter adjusting screw and have tried to use it to bring the meter needle to 1 on the scale with no voltage applied to the input terminals. The indicating meter, being logarithmic, has no "zero". The normal position of

the needle with no input voltage is against the left-hand stop and off scale. The meter should indicate only when a voltage within the range of the instrument is applied to its input terminals.

9. CALIBRATION ADJUSTMENT - Normally, no attention need be given to the matter of calibration as the large amount of feedback in the instrument gives it sufficient inherent stability to maintain the original factory calibration within the accuracy specified. However, to correct errors which might result from the cumulative effects of aging of tubes or from the cumulative effects of wide variations in characteristics of replacement tubes from average tubes, a variable control has been provided which allows the calibration to be shifted a small amount. This control is located on the AC output jack side of the chassis. Access to the chassis is obtained by removing the panel from the outer case by loosening the four nickle-plated screws (not the Phillips head screws) on the face of the panel.

In adjusting the calibration of the instrument the source voltage should be a pure sinusoidal wave of any convenient frequency from 50 to 10,000 c.p.s. and the rms indicating voltmeter used as the standard should be accurate to at least 1%.

10. USE AS AN AMPLIFIER - Inserting a standard tip and sleeve telephone plug into the output jack marked "AC OUTPUT" automatically disconnects the indicating meter and makes the amplifier section of the voltmeter usable as a stable high gain preamplifier completely free of AC hum. When the range switch is set for the 0.001 range the gain of the amplifier is 60 plus or minus 0.1 DB which may be reduced to either 40 or 20 DB

by setting the range switch to the 0.1 and 1 volt ranges respectively. The maximum undistorted output voltage of the amplifier is 1 volt and its output impedance is 2700 ohms paralleled by the series combination of 68,000 ohms and 4 mfd. For a capacitive load of not more than 100 mmfds., the amplifier will give a response uniform within $\pm \frac{1}{2}$ DB over the entire frequency range from 2 to 150,000 c.p.s.

Because of the complete absence of AC hum, this amplifier will be found useful for improving the sensitivity of cathode ray oscilloscopes and other applications where the recording or observation of extremely small voltages is necessary.

11. EXTENSION OF VOLTAGE RANGE - The upper limits of the voltage measurable with this voltmeter may be extended to either 1000 or 10,000 volts by employing the 1310A or the 1310B Ballantine Multiplier respectively. Voltages less than 100 microvolts may be measured with this voltmeter by using it in conjunction with the Ballantine Decade Amplifier.

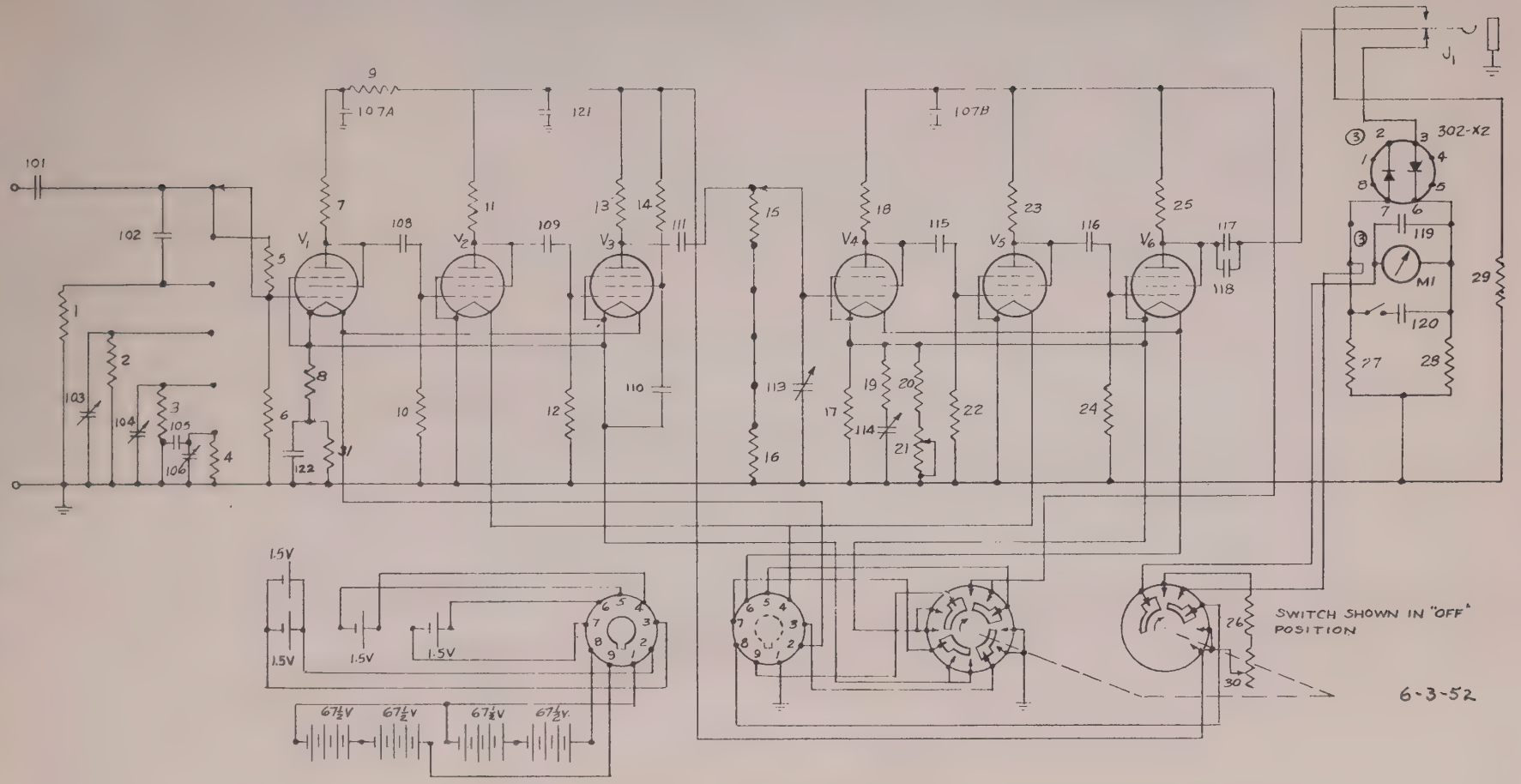
12. USE AS A MICROAMMETER - By using Ballantine Type 600 Precision Shunt Resistors in conjunction with this voltmeter, currents from 1 ampere down to 1/10 of a microampere can be measured over a frequency range of 2 to 150,000 c.p.s. Since the Model 302B Voltmeter is battery operated it is particularly useful for the measurement of currents at points in a circuit which are at a potential above ground.

13. SERVICING - If trouble develops, the condition of the batteries and the battery connectors should be carefully checked. If these are

satisfactory, the [illegible] should be changed. The three tubes on the right side of the chassis (viewed from the panel exterior) should be reasonably free from noise and microphonic defects as may be determined by headphones plugged into the AC output jack. Loosening of the battery retainer will permit rotation of the two "A" batteries and therefore the removal of the tubes.

If the trouble is not remedied by these changes, the instrument should be returned to us for servicing. Before doing this, the trouble should be described to us by letter after which shipping instructions will be furnished.

# MODEL 302B ELECTRONIC VOLTMETER



## LIST OF PARTS *

| Part No. | RESISTORS | |
|---|---|---|
| 1 | 250,000 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 2 | 25,000 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 3 | 2,000 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 4 | 200 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 5 | 2,000,000 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 6 | 2,000,000 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 7 | 180,000 ohms, Type EB, | 5%, Allen-Bradley Company |
| 8 | 140 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 9 | 20,000 ohms, Type EB, | 5%, Allen-Bradley Company |
| 10 | 1,500,000 ohms, Type EB, | 5%, Allen-Bradley Company |
| 11 | 180,000 ohms, Type EB, | 5%, Allen-Bradley Company |
| 12 | 1,500,000 ohms, Type EB, | 5%, Allen-Bradley Company |
| 13 | 20,000 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 14 | 250,000 ohms, Type EB, | 5%, Allen-Bradley Company |
| 15 | 2,000,000 ohms, Type CP-1, | 1%, Wilkor Products |
| 16 | 111,100 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 17 | 420 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 18 | 150,000 ohms, Type EB, | 5%, Allen-Bradley Company |
| 19 | 1,000 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 20 | 1,000 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 21 | 1,000 ohms, Type W Potentiometer, | I.R.C. |
| 22 | 1,500,000 ohms, Type EB, | 5%, Allen-Bradley Company |
| 23 | 150,000 ohms, Type EB, | 5%, Allen-Bradley Company |
| 24 | 1,500,000 ohms, Type EB, | 5%, Allen-Bradley Company |
| 25 | 68,000 ohms, Type EB, | 5%, Allen-Bradley Company |
| 26 | 950,000 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 27 | 10,000 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 28 | 10,000 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 29 | 2,727 ohms, Type CP-$\frac{1}{2}$, | 1%, Wilkor Products |
| 30 | 100,000 ohms, Type Q, | Internatl. Resistance Co. |
| 31 | 220 ohms, Type EB, | 5%, Allen-Bradley Company |

* See attached wiring diagram.

JMM 2/24/52

## REFERENCE LIST OF PARTS *

| Part No. | | CONDENSERS | |
|---|---|---|---|
| 101 | - | 0.5 mfd., 400 volt, | Astron Type ML-4-5 |
| 102 | - | 0.68 mmfd., | Stackpole Type GA |
| 103 | - | 5-50 mmfd., max., | Centralab Type 822AN |
| 104 | - | 550 mmfd., max., 4 plate, | El-Menco Type X304 |
| 105 | - | 0.0025 mfd., mica | Cornell-Dubilier Type 1W |
| 106 | - | 1600 mmfd., max., 9 plate, | El-Menco Type X309 |
| 107 | - | 30-30 mfd., 150 volt, | Cornell-Dubilier Type UP-3315 |
| 108 | - | 0.015 mfd., 200 volt, | Sprague Type 67P15302 |
| 109 | - | 0.5 mfd., 200 volt, | Astron Type MQCP-2-5 |
| 110 | - | 2 mfd., 200 volt, | Astron Type ML-2-2M |
| 111 | - | 0.5 mfd., 200 volt, | Astron Type MQCP-2-5 |
| 113 | - | 1-8 mmfd., | Erie Type 532 |
| 114 | - | 1600 mmfd., max., 9 plate, | El-Menco Type X309 |
| 115 | - | 0.5 mfd., 200 volt, | Astron Type MQCP-2-5 |
| 116 | - | 0.015 mfd., 200 volt, | Sprague Type 67P15302 |
| 117 | - | 2 mfd., 200 volt, | Astron Type ML-2-2M |
| 118 | - | 2 mfd., 200 volt, | Astron Type ML-2-2M |
| 119 | - | 2 mfd., 200 volt, | Astron Type ML-2-2M |
| 120 | - | 250 mfd., 50 volt, | Cornell-Dubilier Type BRH-5025 |
| 121 | - | 100 mfd., 150 volt, | Sprague Type DFP |
| 122 | - | 3000 mfd., 3 volt, | Cornell-Dubilier Type BRHEX |

M1 - Meter, special type obtained from Ballantine Laboratories only.

Tubes - Six Type 1U4, RCA or equal

302-X2-Two Sylvania Type 1N54 Germanium Crystal Diodes

Batteries - Four 1.5 volt, Burgess Type 2F
Four 67.5 volt, Eveready Type 467

* See attached wiring diagram.